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TUNGSTEN

By Gerald R. Smith

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ANNUAL REPORT

TUNGSTEN

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

October 1991

Contents

Domestic Data Coverage 1
Background 1
Definitions 1
Products for Trade and Industry 2
Annual Review 2
Legislation and Government Programs 2
Strategic Considerations 3
Issues 3
Production 4
Consumption and Uses 5
Markets and Prices 5
Foreign Trade 7
World Review 7
Capacity 7
United Nations Conference on Trade and Development (UNCTAD) 7
European Community (EC) .. 8
International Tungsten Industry Association (ITIA) 12
Australia 15
Brazil 15
China 15
India 16
Japan 16
Mongolia 16
Peru 16
Portugal 16
Current Research 16
Outlook 18

COVER PHOTO:
Tungsten materials are commonly used in the production and operation of the automobile. Engine and transmission components are machined with cemented tungsten carbide tool bits. Lubricating oils and gasoline are derived from crude oil recovered using carbide drilling equipment and processed using tungsten-containing catalysts. Automobile lighting accessories and some ignition systems consist of filaments and electrical contact surfaces made of tungsten.

Tables

Table 1.—Salient Tungsten Statistics 1
Table 2.—U.S. Government Tungsten Stockpile Material Inventories and Goals 3
Table 3.—Tungsten Concentrate Shipped From Mines in the United States 4
Table 4.—Major Producers of Tungsten Concentrate and Principal Tungsten Processors in the United States in 1990 4
Table 5.—Production, Disposition, and Stocks of Tungsten Products in the United States in 1990 4
Table 6.—Consumption and Stocks of Tungsten Products in the United States in 1990, by End Use 5
Table 7.—Monthly Price Quotations of Tungsten Concentrate in 1990 6
Table 8.—U.S. Exports of Tungsten Ore and Concentrate, by Country 7
Table 9.—U.S. Exports of Ammonium Paratungstate, by Country 7
Table 10.—U.S. Exports of Tungsten Carbide Powder, by Country 8
Table 11.—U.S. Exports of Tungsten and Tungsten Alloy Powder, by Country 9
Table 12.—U.S. Exports of Miscellaneous Tungsten-Bearing Materials 9
Table 13.—U.S. Imports for Consumption of Tungsten Ore and Concentrate, by Country ... 12
Table 14.—U.S. Imports for Consumption of Ammonium Tungstate, by Country 12
Table 15.—U.S. Imports for Consumption of Ferrotungsten, by Country 13
Table 16.—U.S. Imports for Consumption of Miscellaneous Tungsten-Bearing Materials 13
Table 17.—U.S. Import Duties on Tungsten 16
Table 18.—World Tungsten Annual Mine Production Capacity, December 31, 1990 17
Table 19.—Tungsten: World Concentrate Production, by Country 17
Table 20.—Tungsten: World Concentrate Consumption, by Country 18

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TUNGSTEN

By Gerald R. Smith

Mr. Smith, a physical scientist with 27 years of research and commodity experience with the U.S. Bureau of Mines, has been the commodity specialist for tungsten since 1986. Domestic survey data were prepared by Cheryl Jackson, mineral data assistant; the world production table was prepared by Virginia Woodson, international data coordinator; and the outlook data were prepared by Barry Klein, Economist.

The high melting point, high density, good corrosion resistance, and good thermal and electrical conductivity properties of tungsten and its alloys and the excellent cutting and wear-resistant properties of its carbide are used advantageously in the production of numerous end-use items for domestic and military applications.

Total domestic consumption of tungsten in primary end-use categories increased about 6% in 1990 compared with that of 1989. Demand for products other than carbides, such as steels, superalloys, and mill products, was moderately strong and accounted for approximately 4% of the increase.

Most U.S. tungsten mines remained closed because of the persistently low prices for tungsten concentrate. Average prices for wolframite and scheelite concentrate decreased by 18% and 4%, respectively, in 1990, according to quotations published in Metal Bulletin (London).

Based on a revised assessment of military requirements, the goal for the tungsten family group in the National Defense Stockpile was raised to a level essentially equal to the present inventory in the stockpile.

A summary of the important U.S. and international statistics for 1990 and the previous 4 years are shown in table 1.

TABLE 1

SALIENT TUNGSTEN STATISTICS

(Metric tons of tungsten content unless otherwise specified)

	1986	1987	1988	1989	1990
United States:					
Concentrate:					
Mine production	780	34	W	W	W
Mine shipments	817	34	W	W	W
Value thousands	$5,774	$216	W	W	W
Consumption	4,804	5,506	7,832	7,725	[1]5,878
Shipments from Government stocks	301	708	524	466	—
Exports	34	2	172	203	139
Imports for consumption	2,522	4,414	8,045	7,896	6,420
Stocks, Dec. 31:					
Producer	21	21	21	10	7
Consumer	502	329	499	1,261	1,077
Ammonium paratungstate:					
Production	5,604	5,336	8,357	7,831	[1]6,142
Consumption	6,475	6,363	8,014	8,493	8,787
Stocks, Dec. 31: Producer and consumer	468	292	1,016	915	896
Primary products:					
Production	6,408	7,424	8,068	8,749	[2]4,677
Consumption	7,214	7,228	8,298	7,990	8,496
Stocks, Dec. 31:					
Producer	1,484	1,646	1,890	1,562	[3]1,459
Consumer	860	787	930	761	782
World: Concentrate:					
Production	[r]43,480	[r]42,474	[r]42,202	[r]42,099	[e]40,350
Consumption	44,406	[r]43,853	[r]44,565	[r]44,125	[e]40,393

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Excludes 2 months of "withheld" data.
[2]Includes only hydrogen-reduced metal powder and chemicals.
[3]Excludes tungsten carbide-cast and crystalline.

DOMESTIC DATA COVERAGE

Domestic production data for tungsten are developed by the U.S. Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Tungsten Ore and Concentrate," "Tungsten Concentrate and Tungsten Products," and "Tungsten Concentrate." Of the 51 known mining and processing operations to which survey requests were sent, 94% responded and are represented in the production totals shown in table 1.

BACKGROUND

Definitions

Tungsten, a silvery gray metal, has an atomic number of 74 and an atomic

weight of 183.92. Its most outstanding physical property is its high melting point of 3,410° C, the highest of all metals. Tungsten is one of the heaviest of elements, with a density of 19.3 grams per cubic centimeter at 20° C. It has good corrosion resistance, good thermal and electrical conductivity, and a low coefficient of expansion. At temperatures above 1,650° C, tungsten has the highest tensile strength of all metals.

Tungsten concentrate is sold in units of tungsten trioxide (WO_3). In the United States, sales are based on the short ton unit of WO_3. This is equivalent to 1% of a short ton, or 20 pounds of WO_3, and contains 7.19 kilograms (15.86 pounds) of tungsten. In most other countries, tungsten is sold in the metric ton unit (mtu) and contains 7.93 kilograms (17.48 pounds) of tungsten.

Natural or synthetic scheelite concentrate, in nodular form, is ideal for direct addition to steel melts because the calcium is removed as slag. Fine material in either synthetic or natural scheelite is not desirable because of high dust losses. Wolframite concentrate is not satisfactory for steelmaking because of the manganese and tin content.

Tungsten ores and concentrates are converted into the following intermediate products: ammonium paratungstate (APT), tungstic acid, sodium tungstate, tungsten metal powder, and tungsten carbide powder. Most of the APT is reduced to tungsten metal powder, which then is processed into tungsten carbide powder.

Tungsten alloys and tungsten mill products such as rod, wire, and sheet are produced from hydrogen-reduced tungsten metal powder. The tungsten carbide produced from powder is cemented, usually with cobalt, to form various cutting and wear-resistant tools and parts.

Tungsten chemicals (APT, tungstic acid, and sodium tungstate) are produced as coproducts at some tungsten processing plants and as primary products at others. When not processed further into metal powder, they generally are used in the chemical industry.

Products for Trade and Industry

Tungsten materials can be divided into four major classes, depending on use: (1) a carbide in cutting and wear-resistant materials and welding and hard-facing rods; (2) mill products made from essentially pure metal; (3) an alloy constituent in high-speed and tool and die steels, superalloys, and nonferrous alloys; and (4) various chemicals and compounds for nonmetallurgical applications.

The extreme hardness of tungsten carbide at temperatures exceeding 1,000° C makes it a preferred metalworking material for cutting edges of machine tools subject to intense wear or abrasion and for metal surfaces in forming and shaping dies. The mining and petroleum industries use tungsten carbide in drill bits, in the cutting edges of earth-moving equipment, and in crushing machinery. Tungsten carbide is used widely in wear parts of transportation and electrical equipment.

In most applications, tungsten carbide generally is cemented with a powdered cobalt metal binder by compaction and sintering. The cobalt content can range from about 3 to 25 weight percent, with the higher content providing greater shock resistance at a sacrifice in hardness. Tantalum and/or titanium carbides are used in conjunction with tungsten carbide in certain cutting and chipping tools. Also, coatings such as titanium carbide, titanium nitride, and aluminum oxide on tungsten carbide are used extensively to increase the life of inserts for machining applications.

Mill products made from pure or substantially pure tungsten metal powder are used in significant quantities by the electrical and electronic industries. Tungsten wire is used as the filament in electric lamps and as cathodes for electronic tubes. Disks produced from tungsten rods or sheet are used in automotive distributor points, although this end use is declining as the number of automobiles with electronic ignition systems increases. They are also used as contact points in numerous manufactured products. Tungsten metal is employed as heat and radiation shielding, as electrodes for inert-gas welding, as components of X-ray and cathode-ray tubes, and as heating elements in high-temperature resistance furnaces. Tungsten metal is used by the aerospace industry because it retains its strength at elevated temperature in reducing or inert atmospheres. The use of tungsten as a heavy metal for counterweights and balances, especially by the aircraft industry, has been replaced, to a significant extent, by depleted uranium, which approaches the density of tungsten.

Cast tungsten carbide is used principally as a hard-facing material. In this application, carbide particles are applied by a welding process to provide an abrasion-resisting surface layer on the surface to be coated. The carbide may be initially in the form of rod or loose grains in a tube.

As an alloy constituent, tungsten is used primarily in the production of high-speed steels and tool and die steels. Hardness and oxidation resistance at elevated temperatures are the most important properties possessed by these steels, which are used for machinery and equipment in the metalworking, construction, and mining industries. Certain grades of stainless and other alloy steels contain tungsten to improve wear and abrasion resistance, shock resistance, corrosion resistance, and/or strength at high temperatures.

Tungsten is an important constituent in a wide variety of superalloys and nonferrous alloys. Tungsten-containing superalloys are being utilized increasingly in high-temperature applications for their high-temperature strength and oxidation resistance. Tungsten alloyed with copper or silver is used for electrical contacts to provide wear resistance with adequate electrical conductivity.

Nonmetallurgical applications of tungsten include chemicals used in textile dyes, paints, enamels, toners, and coloring glass. Certain tungsten compounds are luminescent and used as phosphors in pigments, X-ray screens, television picture tubes, and fluorescent lighting. Sodium tungstate is employed as a corrosion inhibitor and a fireproofing agent in textiles. APT is used in making catalysts for the refining of petroleum. Among other chemical applications, tungsten compounds are used in chemical-vapor deposition, as catalysts in other chemical processing, and as laboratory reagents.

The chief nonindustrial use of tungsten is in armor-piercing ordnance, but this has been replaced, in part, by depleted uranium.

ANNUAL REVIEW

Legislation and Government Programs

The National Defense Authorization Act for Fiscal Years 1990 and 1991 included no authority for disposal of tungsten from the National Defense Stockpile during 1990. This was the first time since 1961 that no tungsten was shipped from the defense stockpile.

Goals for the tungsten family group in the National Defense Stockpile were increased based on a revised assessment of military requirements. On June 26, 1990, requirements were raised by 9,178 metric tons (20,234,000 pounds) of tungsten content and established at 32,160 metric tons (70,900,000 pounds) of tungsten content. As a result, the new goal essentially equaled the existing inventory level for the tungsten family group as shown in table 2. The preceding action was taken under authority vested in the Assistant Secretary of Defense and in compliance with the National Defense Authorization Act for Fiscal Years 1990 and 1991.

On August 3, 1990, the Environmental Protection Agency (EPA) published the final regulations under the Clean Water Act affecting nonferrous manufacturing (55 FR 31692). The regulations limited effluent discharges to waters of the United States and the introduction of pollutants into publicly owned treatment works by existing and new sources that conduct metal manufacturing operations in the metallurgical acid plants subcategory. Issued for the purposes of judicial review on August 17, 1990, the regulations became effective on September 17, 1990, and covered the secondary tungsten and cobalt subcategory along with five other subcategories. Amendments included in these final regulations were in response to settlement agreements with six petitioners, published October 30, 1989, (54 FR 45299), regarding regulations in 40 CFR 421 promulgated September 20, 1985, (50 FR 38276). The regulations for the secondary tungsten and cobalt subcategory (40 CFR 421.310-40 CFR 421.317) affected only cobalt effluents, but were directed toward processing methods integrally involved with the secondary recovery of cemented tungsten carbide components.

Regulations regarding "best available technology" and "pretreatment standards for existing sources" were to be complied with on EPA's effective date. The compliance date for "new source performance standards" and "pretreatment standards for new sources" will be the date the new source begins operation.

A bill introduced in the House of Representatives to extend the temporary suspension of duties on tungsten ore concentrates to December 31, 1993, did not proceed beyond the Committee on Ways and Means. As a result, the duty of 37.5 cents per kilogram (17 cents per pound) of tungsten content on imports from countries with most-favored-nation status was reinstated on January 1, 1991. The suspension had been in effect since October 1, 1988.

TABLE 2

U.S. GOVERNMENT TUNGSTEN STOCKPILE MATERIAL INVENTORIES AND GOALS

(Metric tons of tungsten content)

Material	Goals	Inventory by program, Dec. 31, 1990		
		National stockpile	DPA[1] inventory	Total
Tungsten concentrate:				
Stockpile grade	35,938	r24,504	72	24,576
Nonstockpile grade	—	10,055	5	10,060
Total[2]	35,938	34,559	77	34,636
Ferrotungsten:				
Stockpile grade	—	385	—	385
Nonstockpile grade	—	533	—	533
Total	—	918	—	918
Tungsten metal powder:				
Stockpile grade	726	711	—	711
Nonstockpile grade	—	150	—	150
Total	726	861	—	861
Tungsten carbide powder:				
Stockpile grade	907	871	—	871
Nonstockpile grade	—	51	—	51
Total	907	922	—	922

[r]Revised.
[1]Defense Production Act (DPA) of 1950.
[2]Apply the multiplication factor 0.851 to obtain the tungsten metal equivalent used in calculating the total recoverable metal in the tungsten family group.

Strategic Considerations

Tungsten is an important strategic material necessary for defense purposes. Currently, the heavy-metal alloys of tungsten, containing 3% to 10% nickel and small quantities of iron or copper, are used in several of the smaller diameter projectiles for penetrating armorplate. Cemented tungsten carbide parts, which exhibit excellent cutting and wear-resistant properties, are vital to the U.S. metalworking, machining, construction, transportation, mining, and oil and gas drilling industries. Tungsten mill products and powders are essential to the lamp and lighting industry as filaments and electrodes; to the electrical and electronic industries as wear-resistant, electrically conductive contact surfaces; and to the superalloy and steel industries as alloying components. The U.S. Department of Defense relies heavily on the maintenance of a broad domestic production base to cover mobilization contingencies. The entire tungsten industry, from mined ore to manufactured products, thus represents an important component of the U.S. defense policy. The Department of Defense continually assesses the U.S. ability to produce tungsten to ensure that this and other sources of supply are sufficient to meet current and projected levels of demand necessary to preserve the national defense. To that end, the quantity of tungsten in the National Defense Stockpile was increased to a level approximating that of the existing inventory in the stockpile.

Issues

During 1990, China continued to be the dominant supplier of tungsten products to the world market. Concentrate, APT, and ferrotungsten prices generally remained low, while market opportunities were limited by a supply-demand imbalance. Many Western World producers

believed that much of the problem rested with China's failure to place adequate controls on its production, distribution, and pricing policies. As a result of the depressed market, most tungsten mines in the United States and other Western nations remained closed or were operated at reduced capacity during the year. Also, two other mines, one in Australia and one in Brazil, were added to the list of closed mines during the year. Market conditions generally offered little or no economic incentive for producers to explore or develop other tungsten resources. One U.S. company, however, began an effort during the final quarter of the year to request U.S. Government action that would adjust the apparent inequities in the concentrate market. U.S. Tungsten Corp., a subsidiary of Strategic Metals Corp., Danbury, CT, and the operator of the Pine Creek tungsten mine and mill, Bishop, CA, initiated plans to file an antidumping suit against imports of Chinese tungsten ore concentrate.

Some indication of changes in China's tungsten production policies were reported near the end of 1990. Senior officials from China National Minerals and Metals Import and Export Corp. directed that all Government subsidies be removed from tungsten production operations effective January 1, 1991. Essentially, only economically sound operations would be able to continue under this new policy. A few industry officials viewed the Chinese action as an encouraging step toward achieving a more balanced supply-demand condition.

Production

Tungsten mining activity in 1990 was limited because prices for concentrate remained low. Recent statistics on domestic mining as well as a list of major concentrate producers and those processing the various stages of intermediate tungsten materials are shown in tables 3 and 4, respectively. Net production statistics for tungsten metal powders, carbides, and chemicals are shown in table 5.

Curtis Tungsten Inc., Upland, CA, announced a shipment of 24 metric tons of scheelite concentrate in February 1990. This was the first concentrate delivered from Curtis's Andrew tungsten mine, in the San Gabriel Mountains north of Los Angeles, since being operated intermittently during a 10-year period prior to 1985. The company reportedly was recovering its material from relatively rich

TABLE 3

TUNGSTEN CONCENTRATE SHIPPED FROM MINES IN THE UNITED STATES

Year	Quantity		Reported value, f.o.b. mine[1]		
	Metric ton units[2] of WO_3	Tungsten content (metric tons)	Total (thousands)	Average per unit of WO_3	Average per kilogram of tungsten
1986	103,053	817	5,774	56.04	7.07
1987	4,228	34	216	[3]50.34	6.35
1988	W	—	W	—	—
1989	W	—	W	—	—
1990	W	—	W	—	—

W Withheld to avoid disclosing company proprietary data.
[1]Values apply to finished concentrate and are in some instances f.o.b. custom mill.
[2]A metric ton unit equals 10 kilograms of tungsten trioxide (WO_3) and contains 7.93 kilograms of tungsten.
[3]Metals Week, U.S. spot quotations—annual average.

TABLE 4

MAJOR PRODUCERS OF TUNGSTEN CONCENTRATE AND PRINCIPAL TUNGSTEN PROCESSORS IN THE UNITED STATES IN 1990

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
Curtis Tungsten Inc.	Upland, CA.
U.S. Tungsten Corp., a division of Strategic Minerals Corp.	Bishop, CA.
Processors of tungsten:	
Buffalo Tungsten Inc.	Depew, NY.
Canada Tungsten Mining Corp. Ltd.	Fort Madison, IA.
General Electric Co.	Euclid, OH.
GTE Products Corp.	Towanda, PA.
Kennametal Inc.	Latrobe, PA, and Fallon, NV.
Teledyne Firth Sterling	La Vergne, TN.
Teledyne Wah Chang Huntsville	Huntsville, AL.
U.S. Tungsten Corp., a division of Strategic Minerals Corp.	Bishop, CA.

TABLE 5

PRODUCTION, DISPOSITION, AND STOCKS OF TUNGSTEN PRODUCTS IN THE UNITED STATES IN 1990

(Metric tons of tungsten content)

	Tungsten carbide powder				
	Hydrogen-reduced metal powder	Made from metal powder	Cast and crystalline	Chemicals	Total[1]
Gross production during year	8,353	4,151	W	W	12,504
Used to make other products listed here	4,129	W	W	W	4,129
Net production	4,224	W	W	453	4,677
Producer stocks, Dec. 31	778	503	W	178	1,459

W Withheld to avoid disclosing company proprietary data.
[1]Excludes "withheld" data.

veins containing in excess of 1% WO_3. Efforts to produce additional concentrate were hampered by a severe drought that struck southern California for most of the year. Curtis reported in mid-June that it would attempt to increase its assets by entering into an agreement with Gartung Industries Inc., owner of the Strawberry tungsten mine, mill, and 90-man camp in Madera County, CA. These facilities, formerly owned by Teledyne Tungsten, a subsidiary of Teledyne Inc., were operated from July 1978 through December 1986.

U.S. Tungsten Corp., Bishop, CA, continued as the only other company producing tungsten concentrate. The Pine Creek Mine and mill again was operated on an intermittent basis at levels below capacity to provide supplemental feedstock to the company's APT conversion facility. Imported concentrate was the primary source of raw material.

Canada Tungsten Mining Corp. Ltd. suspended operations at its Fort Madison, IA, APT conversion facility at the end of March and did not produce additional APT the remainder of the year. The closure was described as an inventory control measure. The company continued during the year to supply its customers with APT and other upgraded products from its inventories.

Consumption and Uses

Total domestic consumption of tungsten in primary end-use categories (table 6) increased by about 6% in 1990 compared with that of 1989. Demand for cemented carbides in the combined cutting tool, mining tool, oil drilling equipment, and wear-resistant component industries remained strong during the year, ending with an increase of about 2% compared with that of 1989. Demand for other tungsten products, including specialty steels, superalloys, chemicals, and mill products made from metal powder, was moderately strong during the year, accounting for the remaining 4% increase in demand for tungsten products.

Strength in the cemented carbide end-use sector was due, in part, to an increase in oil drilling activity in the final months of the year. As a result of the Iraqi invasion of Kuwait and the subsequent increase in the price of crude oil, the number of operating oil rigs in the United States rose notably. Figures reported by the International Association of Drilling Contractors and Baker Hughes Inc. showed a drill rig count of 1,179 by mid-December 1990 compared with a count of 966 on August 6, immediately after the invasion.

Markets and Prices

Average prices for wolframite and scheelite concentrate decreased by 18% and 4%, respectively, in 1990, according to quotations published in Metal Bulletin (table 7). Wolframite prices generally declined as the year progressed, showing only minor recovery in the second quarter of the year. Scheelite prices were considerably more stable, but also exhibited a declining trend throughout the year.

Domestic APT prices decreased about 4% during the year from a range of $66.69 to $67.79 per mtu in January 1990 to a range of $63.93 to $65.59 per mtu by the end of December. Prices for tungsten metal powder and tungsten carbide powder remained virtually unchanged during the year, quoted at $22.00 and $21.65 per kilogram, respectively.

Wolframite and scheelite prices published by Metal Bulletin are a standard

TABLE 6

CONSUMPTION AND STOCKS OF TUNGSTEN PRODUCTS IN THE UNITED STATES IN 1990, BY END USE

(Metric tons of tungsten content)

End use	Ferrotungsten	Tungsten metal powder	Tungsten carbide powder	Scheelite (natural-synthetic)	Tungsten scrap[1]	Other tungsten materials[2]	Total[3]
Steel:							
Stainless and heat-resisting	64	—	—	W	W	W	64
Alloy	66	—	—	8	—	—	74
Tool	342	—	—	W	W	—	342
Superalloys	5	19	W	7	295	W	325
Alloys (excludes steels and superalloys):							
Cutting and wear-resistant materials	—	86	4,900	—	W	W	4,985
Other alloys[4]	W	8	1	—	W	—	9
Mill products made from metal powder	—	2,181	W	—	—	W	2,181
Chemical and ceramic uses	—	—	—	—	—	50	50
Miscellaneous and unspecified	10	([5])	53	78	167	155	464
Total[3]	488	2,294	[6]4,954	93	462	205	8,496
Consumer stocks, Dec. 31, 1990	33	20	[6]621	11	74	34	793

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Does not include that used in making primary tungsten products.
[2]Includes tungsten chemicals and others.
[3]Data may not add to totals shown because of independent rounding.
[4]Includes welding and hard-facing rods and materials and nonferrous alloys.
[5]Less than 1/2 unit.
[6]Based on reported consumption plus information from secondary sources on companies not canvassed; includes estimates.

TABLE 7

MONTHLY PRICE QUOTATIONS OF TUNGSTEN CONCENTRATE IN 1990

Month	Metal Bulletin (London), scheelite, European market, 70% WO_3 basis[1]				Metal Bulletin (London), wolframite, European market, 65% WO_3 basis[2]				Metals Week, U.S. spot quotations, 65% WO_3 basis, c.i.f. U.S. ports[3]				International Tungsten Indicator, weighted average price,[4] 60% to 79% WO_3	
	Dollars per metric ton unit			Dollars per short ton unit	Dollars per metric ton unit			Dollars per short ton unit	Dollars per short ton unit			Dollars per metric ton unit		
	Low	High	Average	Average	Low	High	Average	Average	Low	High	Average	Average	Dollars per metric ton unit	Dollars per short ton unit
January	56.00	72.00	64.00	58.06	41.00	61.00	50.75	46.04	35.00	44.00	39.67	43.73	57.29	52.41
February	56.00	72.00	64.00	58.06	39.00	58.00	48.57	44.06	34.00	42.00	38.00	41.89	60.14	54.56
March	54.00	72.00	63.33	57.45	39.00	57.00	47.83	43.39	36.00	44.00	39.50	43.54	60.07	54.49
April	54.00	70.00	62.00	56.25	39.00	60.00	48.25	43.77	38.00	46.00	42.25	46.57	57.27	51.96
May	54.00	71.00	62.06	56.30	40.00	60.00	50.00	45.36	36.00	45.00	40.88	45.06	53.27	48.19
June	54.00	72.00	63.00	57.15	40.00	57.00	48.44	43.94	35.00	44.00	39.75	43.82	51.08	46.34
July	54.00	72.00	63.00	57.15	37.00	54.00	46.28	41.98	33.00	42.00	37.50	41.34	59.06	53.57
August	54.00	72.00	63.00	57.15	37.00	53.00	45.00	40.82	33.00	42.00	37.50	41.34	52.91	48.00
September	52.00	72.00	62.44	56.64	37.00	51.00	43.81	39.74	31.00	40.00	35.17	38.77	48.92	44.38
October	52.00	71.00	61.50	55.79	35.00	50.00	42.56	38.61	31.00	39.00	35.00	38.58	54.56	49.50
November	52.00	71.00	61.50	55.79	35.00	49.00	42.50	38.56	31.00	39.00	35.00	38.58	45.04	40.86
December	52.00	71.00	61.50	55.79	37.00	49.00	43.00	39.01	32.00	39.00	35.50	39.13	51.66	46.87

[1]Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $62.61 for 1990. The average equivalent price per short ton unit of WO_3 was $56.80 for 1990.
[2]Low and high prices are reported semiweekly. Monthly averages are arithmetic averages for semiweekly low and high prices. The average price per metric ton unit of WO_3, which is an average of all semiweekly low and high prices, was $46.42 for 1990. The average equivalent price per short ton unit of WO_3 was $42.11 for 1990.
[3]Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average price per short ton unit of WO_3, which is an average of all weekly low and high prices, excluding duty, was $37.98 for 1990. The average equivalent price per metric ton unit of WO_3 was $41.87 for 1990.
[4]Weighted average price per metric ton unit of WO_3 was $54.27 for 1990. The equivalent weighted average price per short ton unit of WO_3 was $49.23 for 1990.

for the industry. Discussions regarding the magazine's tungsten pricing methods were held at the International Tungsten Industry Association's (ITIA) Fifth International Tungsten Symposium in Budapest, Hungary, December 1990. Responses to a questionnaire on pricing, sent to many tungsten industry representatives by Metal Bulletin, served as the basis for most of the discussion. In general, most respondents felt that the published prices were a fair reflection of the market, especially over an extended period of time and given the parameters within which they were formulated. There were some broad criticisms that the prices were influenced to a large degree by merchants, in spite of the fact that only confirmed purchases by consumers are taken into account when formulating the published quotation. Confirmation of consumer transactions is carried out to the best extent possible by contacting the seller in the transaction and/or requesting copies of the sales contract. An additional broad criticism centered on the fact the published quotations did not include also the quantity of transacted material. Although this is true, Metal Bulletin does provide an indication of the quantity transacted by publishing, twice monthly, the tonnages represented in the International Tungsten Indicator price statistics. Furthermore, in situations where there is significant movement in price, there is usually an accompanying article in Metal Bulletin explaining such change that includes some information on the sales quantities involved.

On the matter of the adequacy of the concentrate specifications used to formulate the wolframite price, most respondents were satisfied with the minimum 65% WO_3 limit, but suggested that tin, arsenic, and phosphorus limits be lowered and calcium and antimony limits be added. With respect to the effectiveness with which the quotations reflect the wide range of wolframite grades transacted, most respondents were opposed to splitting the quotation into separate grades or separate origins. This would only serve to reduce further the reportable quantities used in formulating the quotations.

Little change was recommended in the manner in which the present scheelite concentrate prices were quoted. There were, however, some suggestions that the maximum molybdenum content be specified and that artificial scheelite be excluded since it is not, strictly speaking, a concentrate, but rather a chemical product.

Foreign Trade

Comprehensive lists of U.S. export and import trade statistics by material quantity and value and by country of destination and origin are shown in tables 8 through 16. Import tariff rates for the various materials are shown in table 17.

Total U.S. imports of tungsten materials decreased about 13% in 1990 compared with that of 1989. China continued

TABLE 8

U.S. EXPORTS OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY

Country	1989 Tungsten content[1] (metric tons)	1989 Value (thousands)	1990 Tungsten content[2] (metric tons)	1990 Value (thousands)
Austria	42	$320	60	$334
Belgium	—	—	10	56
Canada	8	62	—	—
Germany, Federal Republic of	31	231	9	47
Hong Kong	—	—	1	6
Japan	29	221	—	—
Mexico	([3])	4	6	31
Peru	—	—	10	57
Singapore	86	648	42	234
South Africa, Republic of	([3])	4	—	—
Turkey	6	49	—	—
Total[4]	203	1,539	139	765

[1]Calculated based upon an estimated value of $60 per metric ton unit WO_3.
[2]Calculated based upon an estimated value of $44 per metric ton unit WO_3.
[3]Less than 1/2 unit.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 9

U.S. EXPORTS OF AMMONIUM PARATUNGSTATE, BY COUNTRY

Country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Denmark	—	—	1	$10
France	—	—	48	270
Germany, Federal Republic of	r6	$71	—	—
Hungary	r10	83	10	73
Japan	r50	376	159	1,047
Mexico	r14	121	—	—
Netherlands	r14	123	—	—
South Africa, Republic of	1	10	—	—
Sweden	r14	123	—	—
United Kingdom	r69	595	138	1,056
Total[1]	178	1,503	356	2,456

rRevised.
[1]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

to be the dominant supplier, providing about 50% of all imported tungsten materials, although its share of the import market declined by 11 percentage points from that of 1989. Restrictions on the imports of APT and tungstic acid from China continued through 1990 in accordance with the 1987 Orderly Marketing Agreement (OMA). Of the aggregate APT and tungstic acid import quota of 757.8 metric tons (1,670,687 pounds) tungsten content designated for 1990, approximately 413 metric tons (910,508 pounds) was actually imported. Concentrates, oxides, ferrotungsten, and sodium tungstate continued to represent a significantly greater post-OMA share of tungsten materials imported from China. In 1990, these four types of materials constituted about 90% of all Chinese imports, whereas in 1987 they made up only about 50% of the Chinese imports.

In view of the fact that the present OMA will expire on September 30, 1991, U.S. processors of tungsten began discussions to consider future options to this trade agreement. Among the options reportedly mentioned were an extension of the present OMA for an additional 3 years, an increase in the OMA's scope to include other upgraded tungsten products, and an initiation of other trade actions, such as dumping or countervailing suits.

World Review

Capacity.—The data in table 18 are rated capacity for mines and mills as of December 31, 1989. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Mine capacity for tungsten is based on published reports, maximum production statistics, and estimates. The latter is utilized particularly for certain countries where capacity information is either incomplete or unavailable.

United Nations Conference on Trade and Development (UNCTAD).—The UNCTAD Committee on Tungsten convened its 22d session in Geneva, Switzerland, in December 1990. A Secretariat paper and national statements presented to the Sessional Working Group provided a review of current market conditions. The Secretariat presented a pessimistic outlook for the industry. The present trend of declining prices for tungsten concentrates was expected to continue into

TABLE 10

U.S. EXPORTS OF TUNGSTEN CARBIDE POWDER, BY COUNTRY

Country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Argentina	([1])	$16	([1])	$9
Australia	27	576	90	570
Austria	84	1,202	52	919
Belgium	21	784	9	276
Brazil	17	530	6	178
Canada	253	4,448	221	4,134
Chile	1	29	([1])	3
China	—	—	2	59
Denmark	29	599	39	454
Finland	4	97	3	74
France	82	1,866	33	1,150
Germany, Federal Republic of	196	4,699	150	3,573
Hong Kong	2	56	1	20
India	([1])	19	([1])	6
Ireland	([1])	6	([1])	29
Israel	([1])	5	—	—
Italy	146	4,345	118	3,240
Japan	88	1,291	47	817
Korea, Republic of	8	410	1	67
Luxembourg	5	159	11	244
Malaysia	—	—	([1])	3
Mexico	34	626	22	768
Netherlands	32	889	18	707
Singapore	([1])	12	2	86
South Africa, Republic of	45	573	—	—
Spain	([1])	10	50	772
Sweden	80	1,101	75	1,197
Switzerland	29	621	49	1,071
Taiwan	5	116	5	116
United Kingdom	169	2,087	67	1,295
Venezuela	([1])	4	1	39
Other	3	33	2	69
Total[2]	1,360	27,209	1,074	21,946

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

1991, given the persistent oversupply of material and the weakening demand due to the slowdown in the world economy. The chairman of the session indicated that longer term prospects for the tungsten economy will be influenced by developments in Eastern Europe and Asia as well as by disarmament decisions and environmental considerations. The invasion of Kuwait by Iraq in August 1990 contributed to some uncertainty in the future defense-related demand for tungsten.

Comments from delegates at the meeting indicated that the low prices and large overhang of stocks had led not only to extensive mine closures but also to price-cutting competition among suppliers, especially for concentrates and intermediate materials. In addition, it had led to increased protectionism as evidenced by the recent trade actions against China. Moreover, low price levels had led to the termination of certain bilateral trading arrangements between major consumers and the major producer, but the effects of such changes on the tungsten market remained unclear.

The delegation from China noted that the main cause for the deterioration in the tungsten market since August 1989 was not the increase in world production, but rather the stagnation or steady decline in the domestic demand of the major consumers. They indicated that world tungsten output had not increased substantially, as had been alleged, and that the report of a rise in China's output, specifically, also was incorrect. They explained that the declining activity in the automobile, steel, machine building, and construction industries of the major consuming countries; new technological developments; increased recovery of scrap tungsten; and the growth of substitutes had all contributed to a steady decrease in demand. After stating that they had made efforts to improve the health of the tungsten market, the Chinese proposed that the appropriate form of action by the Committee on Tungsten was one directed toward reaching an agreement among the producers and consumers on measures to stabilize the tungsten market.

The Committee on Tungsten agreed to seek designation as an International Commodity Body (ICB) for the purpose of obtaining access to the account for developmental activities within the Common Fund for Commodities under UNCTAD. A separate item was added to the provisional agenda of the 1991 meeting for the purpose of considering project proposals by Governments and industry that could then be submitted for possible financing under this account. The decision to seek designation as an ICB was based on a proposal made by the delegation from Brazil at the 1989 meeting.

European Community (EC).—Subsequent to its investigation into complaints that China was dumping tungsten materials into the EC, the EC Commission's Council of Ministers reached a final

TABLE 11

U.S. EXPORTS OF TUNGSTEN AND TUNGSTEN ALLOY POWDER, BY COUNTRY

Country	1989			1990		
	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content[1] (metric tons)	Value (thousands)
Australia	35	28	$477	8	7	$124
Austria	85	68	923	48	39	762
Belgium	1	1	18	2	2	87
Brazil	7	6	210	7	5	192
Canada	36	29	790	50	40	1,580
Denmark	1	1	43	—	—	—
Finland	16	13	314	3	3	75
France	15	12	436	6	4	171
Germany, Federal Republic of	135	108	3,214	209	167	5,468
Hong Kong	—	—	—	3	2	23
India	9	7	153	20	16	284
Israel	103	82	1,214	132	105	1,125
Italy	4	3	117	15	12	716
Japan	28	22	695	21	17	531
Korea, Republic of	([2])	([2])	9	1	1	41
Mexico	7	6	173	5	4	162
Netherlands	365	292	4,470	544	435	4,757
Pakistan	([2])	([2])	8	45	36	669
Singapore	20	16	302	1	1	37
South Africa, Republic of	2	1	53	2	2	50
Spain	—	—	—	2	1	50
Sweden	19	15	153	4	3	21
Switzerland	7	6	234	6	5	334
Taiwan	21	17	538	16	13	415
Turkey	2	1	42	2	2	54
United Kingdom	32	26	865	82	66	832
Other	4	2	103	1	([2])	27
Total	954	762	15,554	1,235	988	18,587

[1]Tungsten content estimated by multiplying gross weight by 0.80.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 12

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Country	1989		1990	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Tungsten and tungsten alloy wire:				
Argentina	([1])	$8	([1])	$12
Belgium	([1])	23	([1])	10
Brazil	4	293	7	486
Canada	9	953	21	1,701
Colombia	([1])	29	—	—

See footnotes at end of table.

TABLE 12—Continued

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Tungsten and tungsten alloy wire—Continued				
Costa Rica	(1)	$27	—	—
France	3	249	3	$300
Germany, Federal Republic of	1	316	1	400
Hong Kong	1	63	1	107
India	19	1,158	21	1,270
Italy	7	622	7	706
Japan	10	954	10	1,217
Korea, Republic of	6	589	2	228
Mexico	9	810	4	431
Netherlands	1	127	1	211
Poland	(1)	24	1	57
Switzerland	(1)	38	(1)	71
Taiwan	12	797	5	435
United Kingdom	6	849	1	240
Venezuela	2	474	(1)	5
Other	4	246	5	380
Total	94	8,649	90	8,267
Unwrought tungsten and alloy in crude form, waste, and scrap:				
Australia	3	81	4	67
Austria	(1)	3	9	222
Belgium	—	—	1	36
Canada	30	602	7	184
Chile	7	211	4	112
France	(1)	2	(1)	3
Germany, Federal Republic of	406	8,377	250	4,893
Israel	29	684	34	805
Japan	(1)	16	16	206
Korea, Republic of	1	43	2	91
Sweden	11	122	33	464
Taiwan	12	269	8	205
United Kingdom	12	286	26	401
Other	16	277	24	519
Total	527	10,973	418	8,208
Other tungsten metal:				
Australia	8	217	6	330
Austria	(1)	3	5	247
Belgium	—	—	(1)	10
Brazil	8	631	2	161
Canada	46	2,371	20	1,103
Colombia	(1)	15	—	—
France	9	341	2	139
Germany, Federal Republic of	25	1,056	20	984
Hong Kong	1	81	(1)	29
India	2	99	3	182

See footnotes at end of table.

TABLE 12—Continued

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Other tungsten metal—Continued				
Ireland	32	$4,124	38	$5,699
Italy	5	411	8	675
Japan	40	4,081	50	5,077
Korea, Republic of	3	358	11	744
Mexico	10	630	4	426
Netherlands	1	174	1	117
Singapore	2	122	2	141
South Africa, Republic of	1	40	1	60
Spain	2	94	3	214
Sweden	2	161	1	138
Switzerland	9	97	([1])	39
Taiwan	3	219	6	519
Thailand	1	68	1	89
United Kingdom	9	792	42	2,078
Venezuela	([1])	4	1	70
Other	11	408	15	483
Total[2]	230	16,597	242	19,753
Ferrotungsten and ferrosilicon tungsten:				
Canada	—	—	2	25
Indonesia	—	—	4	14
Mexico	33	81	17	45
Venezuela	—	—	2	14
Total	33	81	25	98
Other tungsten compounds:[3]				
Belgium	—	—	([1])	4
Canada	—	—	1	7
France	—	—	1	15
Germany, Federal Republic of	3	15	2	29
Mexico	([1])	3	([1])	3
Singapore	([1])	20	([1])	181
United Kingdom	9	29	15	118
Total[2]	12	67	20	357

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes only other tungstates.

Source: Bureau of the Census.

decision on September 24, 1990, on the question of permanent imposition of tariffs on certain tungsten imports from China. In that decision, imports of concentrate, tungstic acid and oxide, and tungsten carbide powder and fused tungsten carbide were made subject to duties of 42.4%, 35%, and 33%, respectively. The duties applied to all exporters to the EC with the exception of China National Nonferrous Metals Import and Export Corp. and China National Minerals and Metals Import and Export Corp. Rather than being subject to the imposed duties, the latter exporters were required to comply with certain undisclosed minimum price standards for their products. According to the Official Journal of the EC, the price standards will have the effect of "increasing the prices of the products concerned, to remove the injury caused to the EC industry. The definitive duties, while substantially lower than the dumping margin, correspond to the minimum price required to ensure that the EC producers receive an adequate return on sales in the case of the concentrates and,

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY

Country	1989		1990	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Austria	47	$346	—	—
Australia	138	1,027	11	$32
Bolivia	753	4,515	1,061	4,613
Burma	29	182	31	148
Canada	—	—	106	1,112
China	5,484	29,573	3,964	18,847
Germany, Federal Republic of	—	—	12	52
Hong Kong	169	1,144	44	284
Japan	32	172	—	—
Mexico	113	834	136	634
Netherlands	—	—	29	138
Peru	666	4,006	744	3,800
Portugal	333	2,580	120	691
Rwanda	—	—	162	950
Sweden	2	5	—	—
Switzerland	11	67	—	—
Thailand	88	476	—	—
Turkey	31	150	—	—
Total	7,896	45,077	6,420	31,301

Source: Bureau of the Census.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM TUNGSTATE, BY COUNTRY

Country	1989		1990	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
China	310	$3,517	413	$3,011
Germany, Federal Republic of	27	388	49	452
Taiwan	30	224	—	—
United Kingdom	64	431	—	—
Total	431	4,560	462	3,463

Source: Bureau of the Census.

in the case of the other products, to remove the injury caused to the EC industry." The provisional duties imposed during the 6 months prior to the final decision were collected at the final duty rates.

International Tungsten Industry Association (ITIA).—The ITIA held its Fifth International Tungsten Symposium in Budapest, Hungary, October 14–18, 1990. At this meeting, 24 papers were presented by speakers from 10 separate nations. Subjects covered included tungsten supply-demand and price trends, pricing methods and specifications, tungsten mine production status in several countries, recent technological advancements in the production of specific

TABLE 15

U.S. IMPORTS FOR CONSUMPTION OF FERROTUNGSTEN, BY COUNTRY

Country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Australia	—	—	13	$90
Belgium	—	—	9	51
China	359	$1,982	455	2,455
Germany, Federal Republic of	1	4	1	5
Hong Kong	—	—	13	74
United Kingdom	—	—	2	63
Total[1]	360	1,986	493	2,739

[1]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Waste and scrap:				
Australia	5	$21	13	$43
Austria	5	37	—	—
Belgium	8	35	—	—
Canada	52	594	30	308
China	192	1,790	99	697
France	—	—	7	29
Germany, Federal Republic of	32	210	15	422
Hong Kong	6	60	1	10
Hungary	5	36	—	—
Israel	114	653	180	1,039
Italy	—	—	8	17
Japan	178	1,085	253	1,205
Korea, Republic of	111	648	25	92
Mexico	10	90	8	73
Netherlands	248	2,216	311	2,585
Singapore	10	102	45	281
South Africa, Republic of	24	143	47	259
Sweden	7	62	7	13
Switzerland	—	—	4	4
United Kingdom	207	1,152	27	304
Other	15	104	—	—
Total	1,229	9,038	1,080	7,381
Unwrought tungsten, except alloys, in lump, grains, and powders:				
Belgium	3	97	5	191

See footnotes at end of table.

TABLE 16—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Unwrought tungsten, except alloys, in lump, grains, and powders—Continued				
Canada	8	$190	11	$368
China	—	—	5	117
Germany, Federal Republic of	32	713	25	759
Japan	4	95	10	323
Luxembourg	(1)	4	—	—
Mexico	(1)	3	—	—
Netherlands	—	—	25	194
Sweden	—	—	17	654
Thailand	—	—	14	65
United Kingdom	37	371	58	658
Other	24	174	(1)	9
Total	108	1,647	170	3,338
Unwrought tungsten—ingots, shot, alloys and other:				
Austria	4	134	4	177
Canada	(1)	10	—	—
China	5	95	7	152
Germany, Federal Republic of	1	66	—	—
Other	(1)	27	1	33
Total	[2]11	332	12	362
Wrought tungsten—wire, plate, sheet, strip, foil, and other:[3]				
Austria	17	2,166	15	2,089
Belgium	7	506	3	376
China	(1)	5	(1)	16
France	1	105	(1)	10
Japan	132	13,840	25	4,793
Korea, Republic of	(1)	8	(1)	2
Netherlands	3	315	2	330
United Kingdom	1	45	5	181
Other	4	902	2	498
Total	165	17,892	52	8,295
Tungstic acid: China	68	615	—	—
Calcium tungstate: Germany, Federal Republic of	4	177	4	163
Sodium tungstate:				
China	328	2,139	122	733
Germany, Federal Republic of	(1)	2	(1)	8
Hong Kong	178	1,375	73	476
Japan	4	137	(1)	5
Total	510	3,653	195	1,222
Tungsten carbide:				
Austria	1	8	(1)	1
Canada	47	1,027	22	256
China	44	783	26	484

See footnotes at end of table.

TABLE 16—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS

Product and country	1989 Tungsten content (metric tons)	1989 Value (thousands)	1990 Tungsten content (metric tons)	1990 Value (thousands)
Tungsten carbide—Continued				
Germany, Federal Republic of	420	$7,602	519	$8,987
Japan	9	36	3	125
Korea, Republic of	38	666	38	642
Luxembourg	29	1,004	24	1,031
Sweden	—	—	26	1,014
United Kingdom	25	518	23	360
Other	24	431	([1])	17
Total	637	12,075	681	12,917
Other tungsten compounds:[4]				
China	[r]280	3,283	341	2,895
Germany, Federal Republic of	([1])	8	2	19
Japan	([1])	1	—	—
United Kingdom	2	22	([1])	2
Other	—	—	—	—
Total	[r]282	3,314	343	2,916
Mixtures, organic compounds, chief value in tungsten: Other	([1])	8	—	—

[r]Revised.
[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.
[3]Estimated from reported gross weight.
[4]Includes oxides.

Source: Bureau of the Census.

tungsten end-use items, and environmental issues associated with tungsten processing methods.

Australia.—The Dolphin scheelite mine on King Island, Tasmania, Australia, was offered for sale in August by North Broken Hill Ltd. Company officials stated that continuing depressed tungsten prices and a declining market for the company's gravity-separation grade concentrate were primary reasons for the offer to sell. Although interest in purchasing the mine was shown by at least four investors, the company was unable to attract an immediate buyer. As a result, the mine was closed at the end of November 1990. The King Island closing left the Kara Mine, Tasmania, Australia, as the only operating tungsten mine in Australia. Annual production of tungsten concentrate in Australia was expected to be reduced by about 80%.

Brazil.—Tungsten concentrate production was reduced by about 40% in 1990 compared with that of 1989 as a result of the closure of the Boca de Lage Mine, Currais Novos, Rio Grande do Norte Province. Tungstenio de Brasil Mineirios e Metais Ltd., the operator of the mine, stopped production after its parent company, Anglo American Corp., failed to renew its contract with the present owner. This closure will drop the country's concentrate production level significantly below its estimated consumption level of 670 metric tons of tungsten content per year. Annual concentrate production and consumption statistics for the world are shown in tables 19 and 20, respectively.

A tungsten concentrate upgrading plant was constructed in conjunction with tungsten mining operations near Currais Novos, Rio Grande do Norte. Operation began in late 1990 and was expected to produce 240 and 120 metric tons per year of ferrotungsten and tungsten carbide, respectively. Mineracao Tomas Salustino S.A., owner and operator of the nearby Brejui tungsten mine, holds a partial ownership in this facility.

China.—In addition to the administrative actions to halt Government subsidies to tungsten operations, certain other moves reportedly were initiated near the end of 1990 to gain more control over tungsten sales, exports, and price structure. The moves included terminating the pricing procedure that fixed sales transactions, in many instances, more than 3

TABLE 17

U.S. IMPORT DUTIES ON TUNGSTEN

HTS No.	Item	Rate of duty effective Jan. 1, 1990	
		Most favored nation (MFN)	Non-MFN
2611.00.0000	Tungsten ores and concentrates	$0.37 per kilogram on tungsten content[1]	$1.10 per kilogram on tungsten content.
2825.90.3000	Tungsten oxides	10% ad valorem	45.5% ad valorem.
2825.90.6010	Tungstic acid	3.7% ad valorem	25% ad valorem.
2827.39.4000	Chlorides of tungsten	10% ad valorem	45.5% ad valorem.
2841.80.0010	Ammonium tungstates	10% ad valorem	49.5% ad valorem.
2841.80.0020	Calcium tungstate	10% ad valorem	49.5% ad valorem.
2841.80.0050	Other tungstates	10% ad valorem	49.5% ad valorem.
2849.90.3000	Tungsten carbide	10.5%; ad valorem	55.5% ad valorem.
2850.00.1000	Other tungsten compounds	10% ad valorem	45.5% ad valorem.
3823.90.3500	Mixtures of inorganic compounds, chief value tungsten	10% ad valorem	45.5% ad valorem.
7202.80.0000	Ferrotungsten and ferrosilicon tungsten	5.6% ad valorem	35% ad valorem.
8101.10.0000	Tungsten powders	10.5% ad valorem	58% ad valorem.
8101.91.1000	Tungsten waste and scrap	4.2% ad valorem	50% ad valorem.
8101.91.5000	Unwrought tungsten	6.6% ad valorem	60% ad valorem.
8101.92.0000	Wrought tungsten—bar, rod, sheet, etc.	6.5% ad valorem	60% ad valorem.
8101.93.0000	Wrought tungsten—wire	6.5% ad valorem	60% ad valorem.
8101.99.0000	Wrought tungsten—other	5.5% ad valorem	45% ad valorem.

[1]Temporarily suspended through Dec. 31, 1990.

months in advance to one that offered the material on a short-term, spot market basis, generally of 1 to 3 months. Steps were also taken to reduce tungsten concentrate production by 30% to decrease global stocks and strengthen market prices.

India.—Sterling Tungsten, a subsidiary of Sterling Computers, began construction of India's first tungsten metal powder production plant in early 1990. The company is collaborating with Lucky Goldstar International, Republic of South Korea, on the technical aspects of construction and operation. India's State-owned Tamil Nadu Industrial Development Corp. holds a 26% interest, and Sterling, 25%. The remainder will be publicly owned. Production is projected to begin by mid-1991 at this Madras, India, facility.

Japan.—Tokyo Tungsten Co. Ltd. reportedly began a significant expansion project at its Toyana tungsten powder production facility near Tokyo. The project is expected to increase the metal powder output of the plant from the present 840 metric tons per year to 1,200 metric tons per year.

Mongolia.—According to published reports, the trial operations that began at the Tsagaan Davaa tungsten mine in September 1988 were discontinued in early 1990. The mining facility, a joint venture between Mongolia and several Hungarian interests, apparently was unable to be operated economically. At full capacity, the operation was expected to treat 36,000 metric tons of ore annually.

Peru.—Production of tungsten concentrate by Minera Regina at its scheelite and ferberite mine southeast of Lima was increased appreciably in 1990 in spite of the generally depressed tungsten prices. According to a company representative, in addition to the increased production, the company had achieved greater processing efficiency and had improved the quality of its product, although only minimal profit had been achieved at the low 1990 price levels. Total Peruvian production in 1990, of which Minera Regina accounted for 70%, was about 1,200 metric tons tungsten content. Minera Regina's production was increased by approximately 30% compared with that of 1989.

Portugal.—In mid-October 1990, Charter Consolidated Ltd., London, completed the sale of its 75% interest in Portugal's Beralt Tin and Wolfram Ltd., which, through its Portuguese subsidiary, owns 80.55% of the Panasqueira Tungsten Mine near Fundao, Portugal. The purchaser, Minorco SA, an affiliate of Charter Consolidated, has other significant mining interests and additional Portuguese investments. Minorco's plans for the mine were not revealed.

Current Research

Several advancements in tungsten carbide (WC) technology were reported during 1990. Tungsten carbide spray coatings of improved quality were produced with a Super-D-Gun, developed by Union Carbide Coatings Service Corp., which produces higher supersonic speeds than the original D-Gun.[1] A mixture of oxygen and acetylene explodes in the presence of the coating powder in a detonation chamber. The expanding gases reach a temperature of about 4,000° C and accelerate the coating powders to supersonic speeds, thereby improving the bond strength, density, and

TABLE 18

WORLD TUNGSTEN ANNUAL MINE PRODUCTION CAPACITY, DECEMBER 31, 1990

(Metric tons tungsten content)

	Rated capacity[1]
North America:	
Canada	3,000
Mexico	300
United States	3,700
Total	7,000
South America:	
Argentina	40
Bolivia	1,300
Brazil	500
Peru	1,200
Total	3,040
Europe:	
Austria	1,300
Czechoslovakia	50
Portugal	1,400
Spain	100
Sweden	350
U.S.S.R.	9,200
Total	12,400
Africa:	
Rwanda	150
Uganda	10
Zaire	30
Zimbabwe	30
Total	220
Asia:	
Burma	500
China	21,000
India	20
Japan	300
Korea, North	1,000
Korea, Republic of	1,500
Malaysia	10
Mongolia	500
Thailand	500
Turkey	200
Total	25,530
Oceania:	
Australia	2,250
New Zealand	10
Total	2,260
World total	50,450

[1]Includes capacity at operating mines as well as mines on standby basis.

TABLE 19

TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY[1]

(Metric tons of tungsten content)

Country	1986	1987	1988	1989	1990[e]
Argentina	20	[r]14	[r]13	20	16
Australia	1,600	1,150	[r]1,616	[r]1,371	900
Austria	1,387	1,250	1,235	[e]1,245	1,250
Bolivia	1,095	638	900	[r]1,118	1,200
Brazil	875	[r]800	[r]738	[r]679	[2]422
Burma	715	493	307	[e]300	300
Canada	1,959	—	—	—	—
China[e]	15,000	21,000	21,000	21,000	21,000
Czechoslovakia[e]	50	45	50	50	50
France	987	—	—	—	—
India	23	26	[r]19	[r]12	13
Japan	579	259	266	[r]296	250
Korea, North[e]	1,000	500	500	500	1,000
Korea, Republic of	2,455	2,375	2,029	[r]1,701	[2]1,255
Malaysia	4	—	—	—	—
Mexico	294	213	206	[r]170	200
Mongolia[e]	1,500	1,500	[r]1,000	[r]1,000	500
New Zealand[e]	([2 3])	5	5	5	—
Peru	742	[r]205	[r]432	[r]961	1,200
Portugal	[r]1,637	1,207	1,382	[r]1,381	1,405
Rwanda	13	[r]11	[r]3	[r]105	100
Spain	495	81	80	[r]81	80
Sweden	357	[r]574	[r]420	[r]80	—
Thailand	475	705	651	[r]603	290
Turkey	[r]206	[r]163	[r]125	[r e]100	100
Uganda[e]	4	4	4	4	4
U.S.S.R.[e]	9,200	9,200	9,200	9,300	8,800
United States	780	34	W	W	W
Zaire	27	21	20	[r]16	14
Zimbabwe[e]	1	1	1	1	1
Total	[r]43,480	[r]42,474	[r]42,202	[r]42,099	40,350

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1]Table includes data available through May 8, 1991.
[2]Reported figure.
[3]Less than 1/2 unit.

surface quality of the coating. This wear-resistant coating exhibits compressive residual stress that also improves the fatigue resistance of the coating on substrates such as 4130 steel, 7075 Al, and Ti-6Al-4V.

Either chemical compounds or amorphous mixtures containing tungsten and cobalt were reacted in a gas mixture of controlled carbon concentration to produce a nanophase (ultrafine) WC-cobalt (Co) composite powder.[2] Nanophase WC-23Co powder, after consolidation and formation of a wear-resistant coating by low-pressure plasma (ionized gas) spraying, exhibited good wear resistance and a lower coefficient of friction than conventional WC-Co coatings.

Alloys of WC-6.3Co and WC-6.15Ni implanted with chromium, molybdenum, and titanium ions exhibited lower overall corrosion rates and improved resistance to excessive localized corrosion in accelerated electrochemical corrosion

TABLE 20

TUNGSTEN: WORLD CONCENTRATE CONSUMPTION, BY COUNTRY[1]

(Metric tons of tungsten content)

Country[2]	1986	1987	1988	1989	1990[e]
Argentina	25	65	[e]30	[r]38	30
Australia	94	[e]200	[e]120	[e]130	100
Austria[e]	2,000	2,000	2,100	1,800	1,800
Belgium-Luxembourg	30	[e]50	[e]50	[r]2	—
Brazil	672	867	753	[e]688	670
Bulgaria[e]	100	100	100	100	100
Canada[2]	12	10	10	10	10
China[2 3]	[r]8,500	[r]9,000	[r]9,000	[r]9,000	11,000
Czechoslovakia[e]	1,300	1,300	1,300	1,300	1,300
France	667	269	34	—	—
Germany, Federal Republic of:					
Western states[4]	1,720	1,863	2,144	[r]2,576	500
Eastern states[e]	300	300	300	300	300
Hungary[e]	400	400	500	500	400
India	230	[e]250	[r]87	[r]200	200
Italy[4]	80	86	[r]20	[r]—	—
Japan	2,145	[r]2,119	1,980	1,578	1,500
Korea, North[e]	800	500	500	500	500
Korea, Republic of	1,987	1,950	1,580	[r]2,000	2,000
Mexico	42	64	9	[e]5	5
Netherlands[e]	350	300	330	350	300
Poland[4]	1,264	744	424	[r]—	—
Portugal	40	20	—	—	—
South Africa, Republic of	250	[r]203	[r]242	[r]173	200
Spain[4]	159	[r e]20	[r e]20	—	—
Sweden	855	567	550	[r e]600	550
U.S.S.R.[e]	[r]15,000	[r]15,000	[r]14,500	[r]14,500	13,000
United Kingdom[e]	580	[r]100	[r]50	[r]50	50
United States	4,804	5,506	7,832	7,725	[5]5,878
Total	44,406	[r]43,853	[r]44,565	[r]44,125	40,393

[e]Estimated. [r]Revised.
[1]Source, unless otherwise specified, is Tungsten Statistics, 1989 and 1990, Annual Bulletin of the UNCTAD Committee on Tungsten.
[2]Estimated by the U.S. Bureau of Mines.
[3]Combined internal consumption plus that which was processed to intermediate products and subsequently exported.
[4]Apparent consumption, production plus imports minus exports.
[5]Reported figure; excludes 2 months of "withheld" data.

tests using dilute sulfuric acid and dilute sodium chloride-sodium sulfate solutions.[3] The most promising results were obtained with implanted molybdenum ions.

Composites of Fe-5WC and Fe-20WC exhibiting excellent wear resistance were prepared using hot isostatic pressing (HIP) methods.[4] Dense, pore-free composites were obtained by minimizing the reaction between the iron matrix and the WC particles at pressures from 50 to 200 mega Pascals and a temperature of 800° C. Wear resistance of the composite increased as the HIP pressure was increased.

The wear resistance of plasma-sprayed WC-Co coatings was improved by infiltration with copper alloys.[5] One such alloy consisting of copper, nickel, and phosphorus served as an excellent infiltrant. Hardness of the infiltrated coatings compared favorably with that of conventional cemented WC-Co material.

OUTLOOK

Total apparent consumption of tungsten was correlated with three economic indicators to provide a basis for a statistical projection of tungsten demand through 1995.

Correlation was poor between the consumption data and the Federal Reserve Board (FRB) indexes of Industrial Production-Total and Industrial Production-Metalworking Machinery. Correlation was fair between the consumption data and the FRB index of Industrial Production-Construction and Allied Equipment. On the basis of this indicator, total apparent consumption of tungsten in 1995 was estimated to be about 12,150 metric tons. This corresponds to an average increase of about 2.5% per year over the 1989 level of 10,475 metric tons. Reports by industry spokesmen and studies revealed by independent market analysts apparently share the view that a 3% to 4% average annual increase in total tungsten demand is realistic for the short term. There is expected to be somewhat higher demand for metal powder in the short term due to the anticipated growth in the powder metallurgy market. Demand for tungsten carbide powder, on the other hand, is not expected to increase as rapidly. Growth in the demand for this material will continue to be tempered, particularly in the cemented carbide tool industry, by further competition from substitute materials, including ceramics, ceramic composites, polycrystalline diamond, and cubic boron nitride. Further slowing the rate of demand for these cemented carbide products will be the increased use of ceramic coatings to extend the life of the carbide. In addition, increases in the production of near-net-shape products by techniques such as precision casting, rolling and forging, and powder metallurgy will lessen machining requirements.

Information reported by manufacturers of machine tool equipment indicated that demand for these items could be down as much as 8% in 1991 compared with that of 1990. Such a decline in business activity would likely have a temporary effect on the demand for the cemented carbide tools and cutting inserts

associated with the operation of this machining equipment. A rebound in the demand for machine tool equipment will be expected in 1992. Machine tool requirements in the automotive and aerospace sectors are expected to increase as the economy begins to strengthen in many industrialized countries. Furthermore, solid growth potential reportedly exists in reindustrialized Eastern Europe as well as the United States, where energy exploration and conservation approaches will require new tooling equipment.

Supplies of tungsten concentrate and intermediate materials for U.S. consumption are expected to be sufficient in spite of the continued lack of production at domestic mines in recent years. Actions initiated by the Chinese Government in late 1990 to gain further control over tungsten production, distribution, and pricing will very likely alter the sources of new tungsten supply if implemented for an extended period of time.

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